Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/19
CANADA
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

FISSION-GAS BEHAVIOUR IN UO_2 FUEL

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1. It is known that relatively large bubbles appear and grow in UO_2 fuel at high irradiations. Designers of fuel for burn-up much above 20 000 MWd/tonne U (5×10^{20} fissions/cm^3) need to know how the fission gas will distribute between such bubbles, designed void spaces and the body of the oxide. Experiments to establish understanding of the phenomena are discussed.

2. These experiments confirmed by prototype fuel irradiation indicate that fission-gas release is not a problem with our present power reactor design. For some other designs it appears necessary to consider many of the observed phenomena of fission-gas migration. Experiments have shown that some of the fission gas will migrate to internal traps in the UO_2 rather than escape into void spaces of the fuel element. Other experiments have shown that considerable xenon is re-absorbed from the gas into the oxide. The overall behaviour is strongly dependent on temperature and thermal gradients as well as previous history, stoichiometry of the oxide, porosity, mechanical constraint, and the total irradiation.

3. The following observations from recent experiments are reviewed:

3.1 The apparent diffusion constant, obtained by annealing sintered UO_2 after irradiation, decreases with time in a way that suggests not only trapping of gas in closed pores but also some re-absorption from the pores.

3.2 After irradiated UO_2 had been annealed at 1700°C for 3 hours to allow fission xenon to diffuse, pulverizing released 55% of the total xenon.

3.3 The fraction of fission xenon that is free to diffuse in post-irradiation annealing is decreased by increasing the prior irradiation exposure.

3.4 The migration of lenticular "voids" up a thermal gradient, over the range 1700 to 2200°C, can be very rapid and is believed to sweep the fission gases towards the fuel centre. Fuel cracking during reactor shutdown would liberate the gas from any exposed "voids".

3.5 Very low irradiation at temperatures up to at least 250°C causes the attachment of xenon to UO_2 surfaces exposed to the gas. Much of this gas is released by heating to 400°C. Very little remains attached above 800°C.

3.6 Longer irradiation results also in much more firmly attached xenon that is not significantly released below 1200°C. The amount embedded is roughly proportional to the irradiation, gas pressure and exposed surface. Samples have contained amounts up to 3.6 times the total produced by fission at 2500 MWd/tonne U.

3.7 In one series of experiments considerable isotopic disproportionation was observed in the absorbed xenon. This appears attributable to several processes of migration through narrow channels and over surfaces.

3.8 Post-irradiation studies on several UO_2 rods showed the expected sigmoidal distribution of fission-product xenon from surface to centre. However, in another rod the lowest xenon concentration did not correspond with the highest temperature. Almost complete retention occurs in dense UO_2 below about 1000°C for irradiations up to 10 000 MWd/tonne U.

3.9 Observed burst releases of fission gas appear attributable, in association with surface trapping, to stoichiometric equilibration, evaporation along fission-fragment tracks and to a lesser extent to other phenomena such as nuclear recoil.